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(54) **DETERMINING POWER OVER ETHERNET IMPAIRMENT**

(71) Applicant: **Marvell International Ltd.**, Hamilton (BM)

(72) Inventors: **Tak-Lap Tsui**, Sunnyvale, CA (US); **Runsheng He**, Sunnyvale, CA (US); **Ozdal Barkan**, Mountain View, CA (US); **Dance Wu**, San Jose, CA (US)

(73) Assignee: **Marvell International Ltd.**, Hamilton (BM)

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  CPC *H04B 3/468* (2013.01); *H04B 3/237* (2013.01)

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(57) **ABSTRACT**

A system and method of determining an unbalanced current condition in Power over Ethernet applications are disclosed. In some implementations, a user or network administrator may be notified of potential impairments due to unbalanced current.

20 Claims, 3 Drawing Sheets
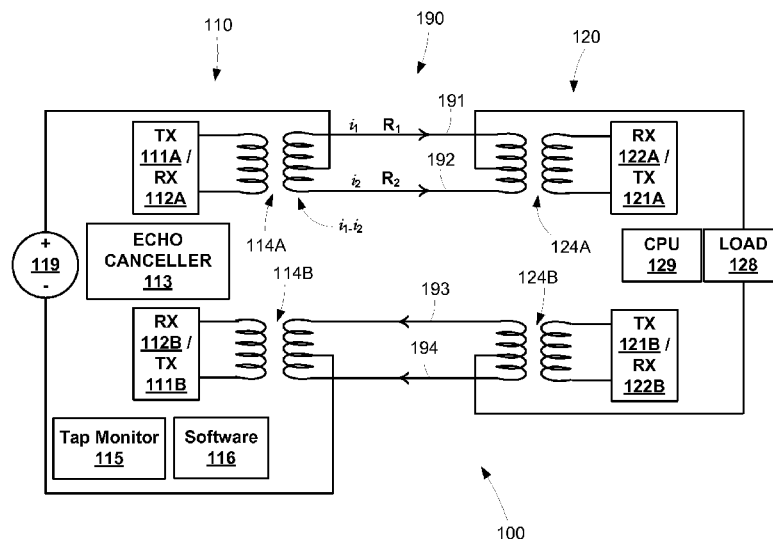
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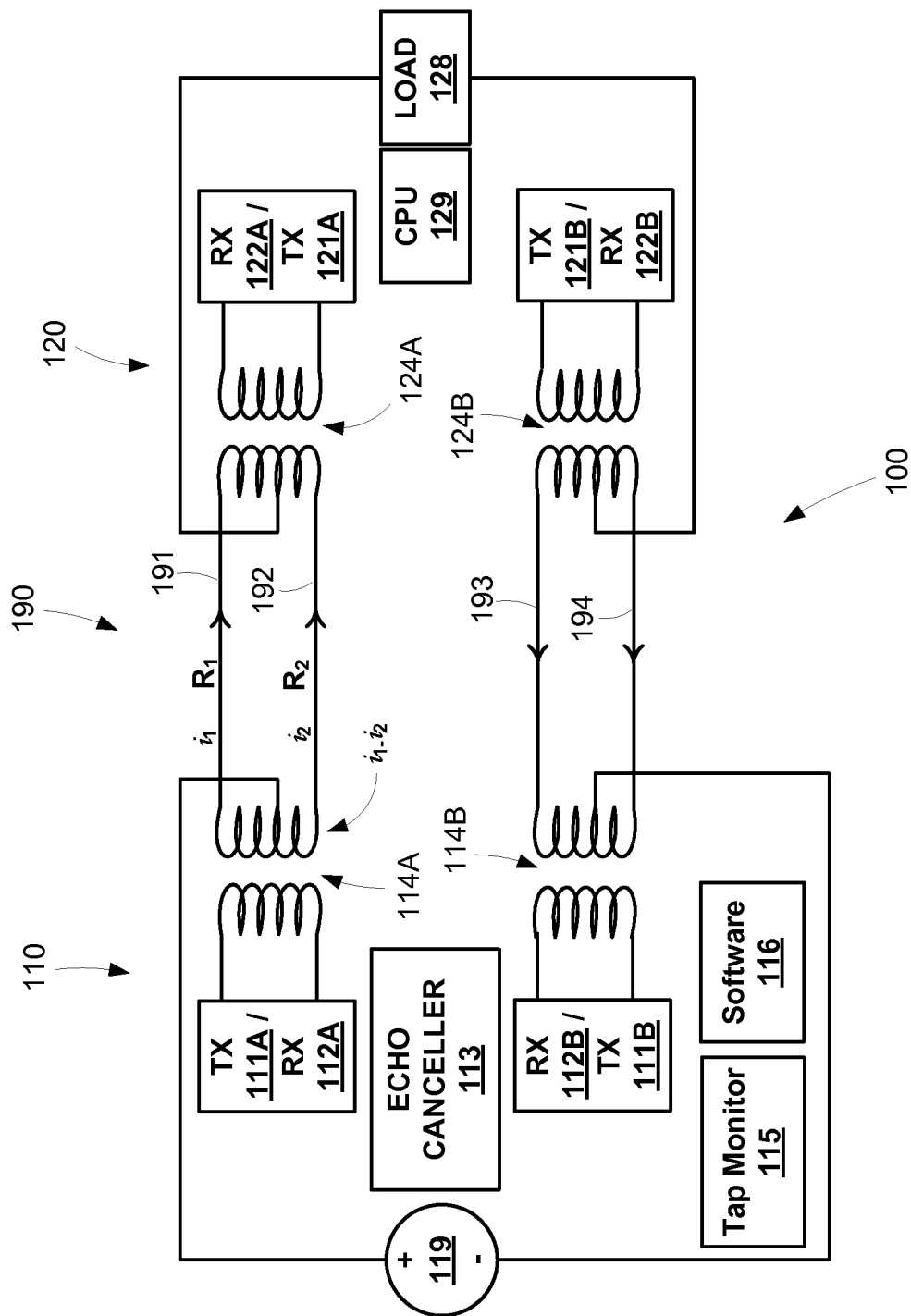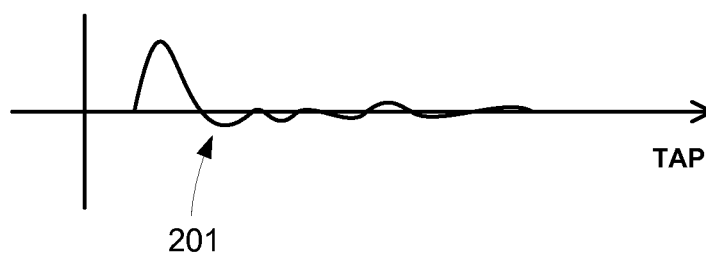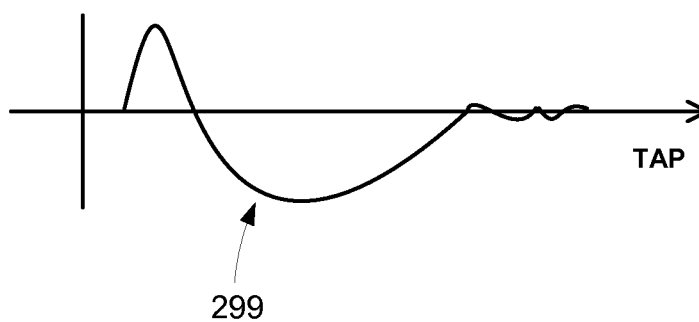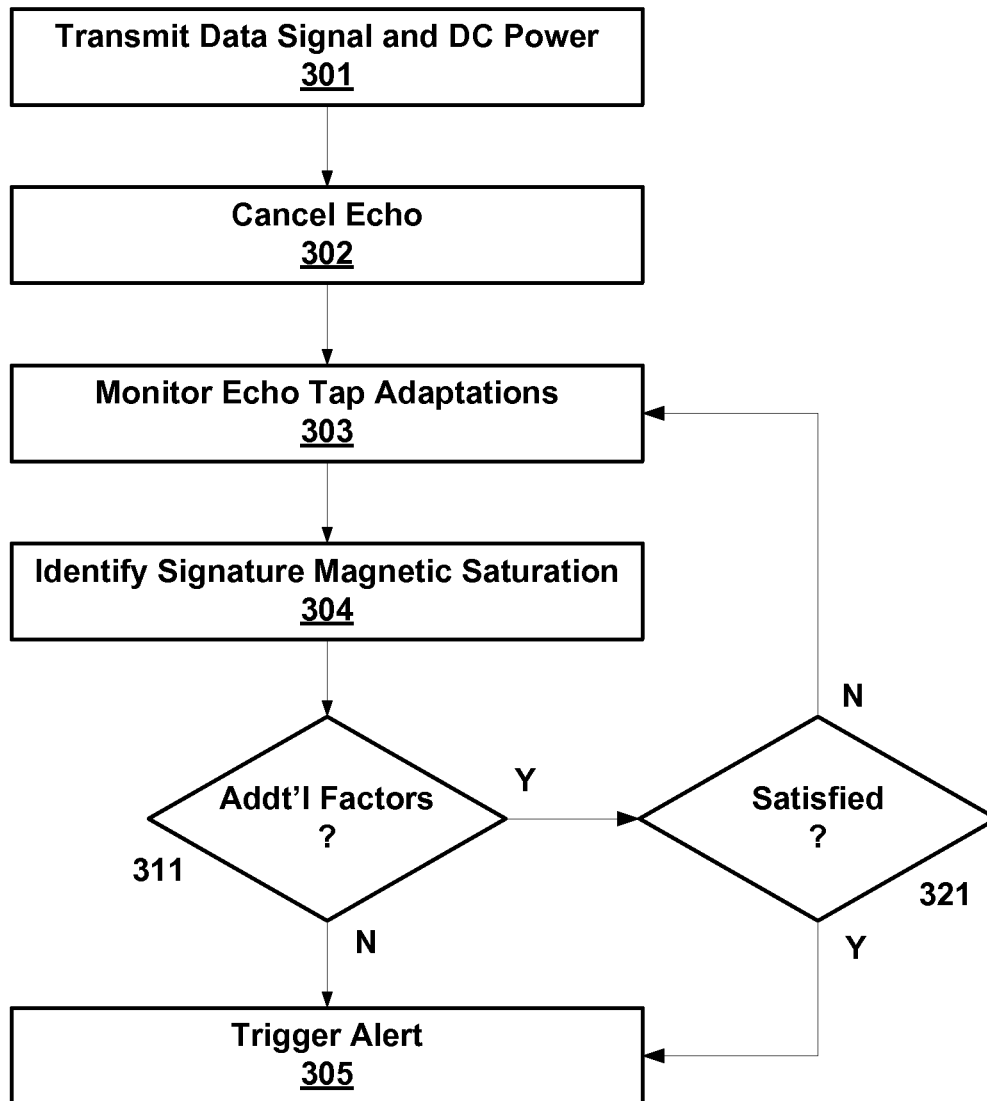
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FIG. 1

TAP

201

FIG. 2A

TAP

299

FIG. 2B

Transmit Data Signal and DC Power
301

Cancel Echo
302

Monitor Echo Tap Adaptations
303

Identify Signature Magnetic Saturation
304

Addt'l Factors
?
311

Satisfied
?
321

N

Y

N

Y

Trigger Alert
305

FIG. 3

DETERMINING POWER OVER ETHERNET IMPAIRMENT

RELATED APPLICATION

This application claims is a continuation of and claims priority to U.S. Utility patent application Ser. No. 12/323,292 filed Nov. 25, 2008 which claims priority to U.S. Provisional Patent Application Ser. No. 61/007,240 filed Dec. 11, 2007, the disclosure of which are incorporated by reference herein in their entirety.

BACKGROUND

Aspects of the present invention relate generally to Power over Ethernet technologies, and more particularly to a system and method of determining an unbalanced current condition in Power over Ethernet applications.

Recent technological and market developments have resulted in a growing interest in Power over Ethernet (PoE) applications such that many network equipment manufacturers and systems integrators are endeavoring to design and implement enhancements to PoE. PoE has been standardized in a specification promulgated by the Institute of Electrical and Electronics Engineers (IEEE), specifically, the IEEE 802.3af standard for providing power to data terminal equipment (DTE) via a medium dependent interface (MDI).

In operation, PoE is similar to that of a traditional telephone network in which operating power necessary for the electrical components in the telephone is delivered from the central office through the telephone cable, i.e., it is not necessary to couple the telephone to an independent external power source. In PoE implementations, power is typically delivered to DTE devices from Ethernet switches or power sourcing equipment (PSE) via the local area network (LAN) cabling itself. Operating power provided through the LAN cables is then employed to power Internet Protocol (IP) telephones, wireless access points, security or web cameras, and the like. This technology does not require alteration of the Ethernet infrastructure, and eliminates the requirement that networked DTE devices be supplied with operating current from an independent external power source.

It is expected that the existing IEEE 802.3af standard will soon be augmented by another specification, IEEE 802.3at (or PoE+), which is under development. As currently contemplated, PoE+ will support increased current requirements, and accordingly, some of the challenges associated with supplying direct current (DC) power over category 5 (Cat5) or category 3 (Cat3) network cables will be exacerbated by the higher current levels prescribed by IEEE 802.3at. One potential impediment is a current mismatch between the positive and negative (+/−) wires of a given twisted pair. In some instances where the current is not equal, a net induced magnetic field can saturate transformers and decrease effective open circuit inductance (OCL), thus causing droop and other signaling degradation. Various factors may influence such a current mismatch including, but not limited to, different respective resistances in the +/− wires, and different contact qualities or contact resistances at the connections. Regardless of the source of the mismatch, however, the end result is the same; attendant signal degradation can cause packet errors or even link instability or failure.

Hence, it may be desirable in some circumstances to provide a method and system that effectively identify an unbalanced current condition in PoE applications.

SUMMARY

Embodiments of the present invention overcome the above-mentioned and various other shortcomings of conventional technology, providing a system and method of determining an unbalanced current condition in Power over Ethernet applications. In some implementations, a user or network administrator may be notified of potential impairments due to unbalanced current.

In accordance with one embodiment, a method of determining an impairment in a Power over Ethernet application may generally comprise monitoring operation of an echo canceller associated with a PHY device, determining when an echo energy reflected back to the device is above a threshold, and triggering an alert responsive to the determination. Either a power sourcing equipment device or a data terminal equipment device may be configured to perform the forgoing method.

In accordance with another embodiment, a device for use in a Power over Ethernet application may generally comprise: a transmitter; a receiver; an echo canceller to remove echo energy from a signal received at the receiver; and a tap monitor to monitor operation of the echo canceller; wherein output from the tap monitor may be employed to trigger an alert responsive to a determination that the echo energy is above a threshold.

The foregoing and other aspects of various embodiments of the present invention will be apparent through examination of the following detailed description thereof in conjunction with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified block diagram illustrating components of one embodiment of a Power over Ethernet architecture.

FIGS. **2**A and **2**B are simplified graphs plotting tap adaptations in an echo canceller.

FIG. **3** is a simplified flow diagram illustrating general operation of one embodiment of a method of determining signal impairment due to an unbalanced current condition.

DETAILED DESCRIPTION

While the possibility of unbalanced current resulting in transformer saturation in PoE implementations is generally known, no single solution has been adopted by the industry. Many solutions have been proposed to address this issue, and several are under active consideration at the IEEE 802.3at development meetings. The proposed solutions generally involve additions or alterations of the magnetics or of the physical (PHY) layers of the power sourcing equipment (PSE) or the powered devices (or data terminal equipment (DTE)). Additionally, most proposed solutions waste power by implementing resistors added to the magnetics path. While potentially feasible, these strategies to eliminate or to minimize the effects of unbalanced current in PoE have associated cost and size penalties that cannot be avoided. In contrast, embodiments of the invention set forth herein do not increase the size or the cost of the transformers and the PHY layer components, and will not waste any power.

Turning now to the drawing figures, FIG. **1** is a simplified block diagram illustrating components of one embodiment of a Power over Ethernet architecture. In the FIG. **1** embodiment, PoE architecture **100** generally comprises a PSE device **110** coupled to a DTE device **120** via a network cable **190**.

In accordance with one embodiment, the PHY layer connection between PSE device **110** or DTE device **120** and the line-side (i.e., the LAN cable, such as a Cat5 or Cat3 cable), as well as digital signal processing (DSP) information obtained during the link-up process, may be employed to

determine if a transformer at the transmitting or the receiving device is saturated. In some implementations, hardware register settings may be accessed, for example, to determine that the transformer is saturated; additionally, certain hardware registers may be set or software interrupts may be generated to indicate this condition. Based on this information (i.e., hardware register settings or software interrupts) or in accordance with another trigger mechanism, higher level software may alert a system user or network administrator that corrective action may be appropriate or required. Such corrective action may include ensuring that contacts are clean, changing the LAN cable, or reducing current levels.

PSE device **110** generally comprises PHY devices (i.e., PHY transmitters **111A** and **111B** and PHY receivers **112A** and **112B**), an echo canceller **113**, and a power source **119**. PHY transmitters **111A** and **111B** and PHY receivers **112A** and **112B** may be any PoE compliant PHY layer capable of full-duplex operation and suitable for use in connection with relevant standards including, but not limited to, IEEE 802.3ab, 802.3af, and 802.3at, as well as other standards developed and operative in accordance with known principles. The present disclosure is not intended to be limited to any particular PHY layer structure or architectural implementation.

PHY transmitters **111A** and **111B** may be generally operative to transmit data signals to DTE device **120** via cable **190**. In that regard, PHY transmitter **111A** may be coupled to a twisted pair of wires **191** and **192** associated with cable **190** via a transformer **114A**; similarly, PHY transmitter **111B** may be coupled to a twisted pair of wires **193** and **194** associated with cable **190** via a transformer **114B**. As illustrated in FIG. **1**, PHY receiver **112A** may be operative to receive data signals from DTE device **120** over twisted pair of wires **191** and **192** associated with cable **190** via transformer **114A**, and PHY receiver **112B** may be operative to receive data signals from DTE device **120** over twisted pair of wires **193** and **194** associated with cable **190** via a transformer **114B**.

Output of power source **119** may be electrically coupled to the line-side of transformers **114A** and **114B** as illustrated. In PoE applications, power source **119** may be operative to supply 48 volts of electric potential in accordance with the IEEE 802.3af standard, but other voltages may be desirable in some circumstances. Accordingly, it is contemplated that power source **119** may be implemented to produce electric potentials less than or greater than a nominal 48 volts, depending upon the overall operational characteristics or requirements of the system or communications protocol in connection with which PSE device **110** is intended to be used.

DTE device **120** generally comprises PHY transmitters **121A** and **121B**, PHY receivers **122A** and **122B**, and a load **128**. As described above with reference to PSE device **110**, PHY transmitters **121A** and **121B** and PHY receivers **122A** and **122B** associated with DTE device **120** may be implemented as or generally comprise any PHY layer compatible with (or otherwise suitable for use in connection with) a desired communications standard. As indicated in FIG. **1**, PHY receiver **122A** and PHY transmitter **121A** may be coupled to twisted pair **191**, **192** via a transformer **124A**, and PHY transmitter **121B** and PHY receiver **122B** may be coupled to twisted pair **193**, **194** via a transformer **124B**.

Load **128** may be electrically coupled to the line-side of transformers **124A** and **124B** as illustrated. The depiction of load **128** in FIG. **1** is intended to represent any generic electrical load requiring power to operate DTE device **120** for its intended purpose. Load **128** may generally represent any electrical or electronic component such as an application specific integrated circuit (ASIC) or a microprocessor, for

example. In that regard, in the FIG. **1** embodiment, DTE device **120** is illustrated as comprising a central processing unit **129**, but the present disclosure is not intended to be limited to any particular electrical component or structural arrangement at DTE device **120**.

For example, in some implementations, DTE device **120** may comprise a Voice over Internet Protocol (VoIP) telephone, a wireless (e.g., wireless LAN or Bluetooth) router or access point, a security camera or building access control system, a web camera, or some other electronic device requiring operating power. These various embodiments of DTE device **120** may have different components (such as microprocessors, memories, displays, or a combination of these and other components) requiring power, and these components and component combinations are generically illustrated in FIG. **1** as load **128**. It will be appreciated that DTE device **120** may comprise additional components, such as DC/DC converters, transformers, or voltage regulators, for instance, as necessary or desired to control or otherwise to regulate the operating voltage supplied to load **128**. These additional components may be selected, for example, depending upon the nature and operational characteristics of load **128** and the overall design parameters of DTE device **120**.

As noted briefly above, network cable **190** may generally comprise twisted pair **191**, **192** and twisted pair **193**, **194** that are operative to carry data signals and operating power from PHY transmitter **111A** associated with PSE device **110** to PHY receiver **122A** associated with DTE device **120**; similarly, additional twisted pair **193**, **194** may be coupled between PHY transmitter **111B** associated with DTE device **120** and PHY receiver **122B** associated with PSE device **110**.

It is noted that the FIG. **1** embodiment represents only one example of a typical PoE architecture. A conventional Cat5 network cable generally comprises four twisted pairs, only two of which are employed for 10BASE-T and 100BASE-TX Ethernet communications. Thus, in an alternative embodiment, two spare pairs of wires may be used to supply power in PoE applications; this is in contrast to the FIG. **1** embodiment in which the signal pairs (**191,192** and **193,194**, respectively) are used to deliver power. While the general operation set forth below is applicable to PoE architectures using the signal wires for power transmission, those of skill in the art will readily appreciate that the present disclosure is not intended to be limited to the architecture illustrated in FIG. **1**.

In operation, voltage supplied from power source **119** to transformer **114A** induces currents i_1 and i_2 in wires **191** and **192**, respectively. Ideally, currents i_1 and i_2 are matched or balanced, i.e., of equal magnitude, however, this condition is not always satisfied. For example, respective resistances R_1 and R_2 in wires **191** and **192**, respectively, may differ for various reasons, causing a mismatch or unbalanced current condition in which i_1 is not equal to i_2. Similarly, the various PHY layers at PSE device **110** and DTE device **120** are coupled to cable **190** via an RJ-45 connector, for example, in Ethernet implementations; an imperfect connection caused by pin misalignment or soiled contacts may create a small resistance, resulting in mismatched currents.

In an unbalanced current condition, the line-side coil on transformer **114A** carries a residual current equal to $i_1 - i_2$ (as illustrated in FIG. **1**), which tends to induce a magnetic field between the coils of transformer **114A**. In some situations, particularly where large currents (e.g., such as prescribed by the IEEE 802.3at standard) are supported, transformer **114A** may become saturated, significantly degrading the quality of the data signal transmitted on the signal pair **191**, **192**, increasing bit error rates and instances of packet loss; addi-

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tionally, link stability may be jeopardized, possibly resulting in link loss in some circumstances.

For instance, where a desired magnitude for currents i_1 and i_2 is about 350 mA or greater, even a small percentage difference in R_1 and R_2 may result in a difference between i_1 and i_2 on the order of about 100 mA. The resulting residual current may significantly reduce the inductance of the magnetic coil on the line-side of transformer **114A**. As a consequence, the reduced inductance produces a high-pass filter effect on the data signal to be transmitted via twisted pair **191**, **192** through transformer **114A**. A significant portion (generally at lower frequencies) of the signal sought to be transmitted by PSE device **110** is reflected back as echo, creating poor signal to noise characteristics, particularly in full-duplex communications mode.

Echo canceller **113** may be employed to reduce some of the effects of an induced magnetic field at transformer **114A**. In particular, echo canceller **113** may generally be operative to identify and remove (from a received data signal) data signals that were transmitted from PHY transmitter **111A** (echoes) such that what is received at PHY receiver **112A** is only that signal transmitted by DTE device **120**. Echo canceller **113** may employ adaptive echo cancelling techniques, for instance, based upon knowledge of the data signal transmitted by PHY transmitter **111A**. When magnetic saturation reflects transmitted energy due to reduced inductance at transformer **114A**, echo canceller **113** may remove such reflected energy using any of various echo cancelling strategies. It will be appreciated that echo canceller **113** may also be implemented in a similar manner to remove energy transmitted by PHY transmitter **111B** that is reflected when transformer **114B** is saturated or otherwise suffers from reduced inductance. In some implementations, it may be desirable to provide each respective transceiver pair (i.e., **111A** and **112A**, on the one hand, and **111B** and **112B**, on the other hand) a respective dedicated echo canceller **113**. In such embodiments, PSE device **110** may include multiple echo cancelling hardware devices or functional blocks. Additionally, it will be appreciated that DTE device **120** may employ one or more echo cancellers (not shown in FIG. 1 for clarity) and tap monitors (described below) in a similar manner as that set forth with reference to PSE device **110**.

For example, a static strategy of echo cancellation may simply subtract a portion of the transmitted data signal from a received data signal; the net result of such subtraction should be a "net" received signal, i.e., the signal transmitted from DTE device **120** with any contributions of the signal transmitted by PSE device **110** removed. In common practice, a more sophisticated hybrid strategy may be employed in accordance with which dedicated circuitry may cooperate with the digital signal processing (DSP) operations of echo canceller **113** to eliminate, from a received signal, any echo associated with a transmitted signal.

In that regard, FIGS. **2A** and **2B** are simplified graphs plotting tap adaptations in an echo canceller. The curves plot echo energy on a channel as a function of time. It will be appreciated that echo canceller **113** may generally employ a plurality of taps, or delays. A respective copy of the received signal, delayed by a predetermined time increment, may be processed at each respective one of the plurality of taps. Scaled or weighted signals at each tap may be subtracted from the received signal, removing echo energy.

The plot in FIG. **2A** illustrates a situation in which $i_1=i_2$ in FIG. **1**, and no (or only a minimal) induced magnetic field exists at the line-side magnetic coil in transformer **114A**. The small area **201** of the curve represents echo energy that is effectively handled by echo canceller **113**. In contrast, the plot

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in FIG. **2B** illustrates an unbalanced current condition in which transformer **114A** produces a high-pass filter effect with respect to twisted pair **191**, **192**. The large area **299** of the curve represents echo energy that taxes the capabilities of echo canceller **113**. The signature large area **299** beneath the abscissa in FIG. **2B** indicates that an induced magnetic field has saturated, or is threatening to saturate, transformer **114A**.

In accordance with some embodiments, a system and method of determining PoE impairment may leverage this signature large area **299** by monitoring the adaptation of taps in echo canceller **113**. For example, the area beneath the abscissa may be integrated; computations resulting in areas above a certain threshold may be interpreted as indicating a saturation condition, whereas computations resulting in areas below certain threshold (which may be different) may be interpreted as an indication of operation within normal parameters.

In that regard, a tap monitor **115** may be implemented in cooperation with echo canceller **113** to monitor the operation of echo canceller **113**. In some instances, tap monitor **115** may monitor the tap adaptations as set forth above with reference to FIGS. **2A** and **2B**. Tap monitor **115** may be implemented as hardware (such as embodied in an ASIC, for instance) or as software instruction sets. In an embodiment in which tap monitor **115** is integrated with echo canceller **113**, for example, it may be desirable that tap monitor **115** is a hardware implementation. Alternatively, tap monitor **115** may be incorporated into or used in conjunction with a multipurpose microprocessor or microcontroller. In use, tap monitor **115** may be apprised of the ongoing operation of echo canceller **113** and may examine the function of tap adaptations to identify areas representative of echo energy above a particular threshold. This threshold may be devised from empirical data, for instance, or may be predetermined based upon theoretical or expected values; additionally or alternatively, it may be desirable to implement the threshold as a selectively or dynamically adjustable threshold. In one such embodiment, a user or network administrator may be enabled to alter the threshold in accordance with desirable or experienced operational characteristics of the network. In another embodiment, tap monitor **115** may receive additional input from another component of PSE **110**, for instance from a transceiver pair (**111A/112A** or **111B/112B**), a microprocessor or other controller, or software **116** (described below); accordingly, tap monitor **115** may also be apprised of bit error rates, packet loss, or other relevant communications parameters such that the threshold may be adjusted in real time based upon current operating conditions. In operation of PSE **110**, output from tap monitor **115**, either in isolation or in conjunction with other processing steps, may be employed to trigger an alert as set forth below.

Upon determining that a particular energy threshold has been reached or exceeded, tap monitor **115** may trigger a warning event. In one embodiment, tap monitor **115** may set hardware registers at PSE device **110** (or cause such registers to be set); additionally or alternatively, tap monitor **115** may generate, or cause to be generated, one or more software interrupts. These register settings or interrupts (or some other equivalent trigger mechanism) may generally be indicative of a magnetic saturation condition at transformer **114A**, and may be received or retrieved by higher-level software **116** for additional operations. Software **116** may alert a user or network administrator of the condition, for example, and may additionally recommend corrective action to rectify the unbalanced current at the source of the condition. As noted above, such corrective action may include ensuring that RJ-45 contacts are clean, changing the LAN cable, or reduc-

ing current levels. Also as noted above, the foregoing components and functionality may be implemented at DTE device **120** in a manner similar to that described with reference to PSE device **110**.

FIG. **3** is a simplified flow diagram illustrating general operation of one embodiment of a method of determining signal impairment due to an unbalanced current condition. The sequence of operations depicted in FIG. **3** may be performed by a PSE device **110** or a DTE device **120** as described above with reference to FIG. **1**, for example, or by another suitably configured PoE compatible device.

As indicated at block **301**, an embodiment of a method of determining signal impairment may begin with a PSE transmitting a data signal and DC power. This transmission generally involves coupling a PHY layer to a network cable using appropriate hardware connectors; in one embodiment described above, the transmitting comprises coupling a PSE to a Cat5 cable using an RJ-45 connector.

Echo cancellation may be performed as indicated at block **302**. Typical PSE devices employ various types of echo cancellation to improve signal to noise ratios. In accordance with one aspect of the present invention, a method may monitor operation of an echo canceller associated with the PSE device (block **303**) to identify a signature representative of magnetic saturation (block **304**) at a transformer at the connection between the PHY layer and the line-side of the network cable. As described above with reference to FIGS. **1**, **2A**, and **2B**, this monitoring may comprise monitoring the tap adaptations of the echo canceller in some embodiments. In operation, DSP algorithms at a tap monitor, the echo canceller, or both, may be employed to integrate echo energy over time to identify conditions that are characteristic of magnetic saturation. In the foregoing manner, the method may determine when echo energy reflected back to the PSE is above a predetermined or dynamically variable threshold.

Finally, the method may trigger an alert (block **305**). This alert may be operative to inform a user or network administrator that an unbalanced current condition may be causing magnetic saturation that may adversely affect communications signaling. As set forth above, hardware register settings or software interrupts may be employed to enable software or other instruction sets to generate the alert; as an alternative, an alert may be solely hardware-based, in which case one or more bits in a hardware register may be set as an indication of a fault condition, and the alert may be triggered by this alone. Responsive to the alert being triggered, an output may be provided. For example, the alert may include an audible alarm, for example, or a visual display. In some instances, a recommendation may be supplied along with the alert; for example, the method may recommend, among other things, that contacts be cleaned, that the network cable be replaced, or that current be reduced.

In one embodiment, the trigger operation at block **305** may be responsive to the identification and determination operation at block **304**. In the FIG. **3** embodiment, however, optional additional factors may be considered as indicated at decision block **311**. A determination may be made at block **311** whether additional factors may affect the trigger operation. If no additional factors are involved, flow goes directly to block **305** and the alert is generated. If additional factors are involved, flow goes to decision block **321**, where a determination may be made regarding whether certain criteria are satisfied. For example, minimum or maximum bit error rates or packet loss parameters may be examined, and a decision to generate an alert at block **305** may be influenced not only by reflected energy, but also from these or other real time conditions of network communications. As one example, if a

maximum bit error rate threshold has been set, and a determination is made that the threshold has been exceeded, then that criterion has been satisfied; flow would proceed from decision block **321** to trigger operation at block **305**. If, however, the bit error rate threshold has not been exceeded, then flow may loop back to block **303**. Any of various additional factors or communications parameters may be considered at blocks **311** and **321**, and these may be application-specific or otherwise influenced by the system in which the PSE is deployed.

It is noted that the arrangement of the blocks in FIG. **3** does not necessarily imply a particular order or sequence of events, nor is it intended to exclude other possibilities. For example, the operations depicted at **303** and **304** or at **304** and **305** may occur substantially simultaneously with each other; similarly, the determinations made at decision blocks **311** and **321** may be incorporated in a single operation, or may be eliminated in some instances.

Several features and aspects of the present invention have been illustrated and described in detail with reference to particular embodiments by way of example only, and not by way of limitation. Those of skill in the art will appreciate that alternative implementations and various modifications to the disclosed embodiments are within the scope and contemplation of the present disclosure. Therefore, it is intended that the invention be considered as limited only by the scope of the appended claims.

What is claimed is:

1. A method of determining an impairment in a Power over Ethernet application, said method comprising:
   monitoring operation of an echo canceller with a tap monitor, the echo canceller being associated with a physical device, the echo canceller configured to remove echo energy from a signal;
   measuring the echo energy over time;
   determining that the measured echo energy over time is above a threshold indicating a saturation condition; and
   responsive to said determining that the measured echo energy over time is above the threshold, triggering an alert indicating that the saturation condition is caused by an unbalanced current.

2. The method of claim **1**, wherein said monitoring comprises monitoring tap adaptations of the echo canceller to identify areas representative of the measured echo energy being above the threshold.

3. The method of claim **1**, wherein said triggering comprises setting one or more bits in a hardware register.

4. The method of claim **1**, wherein said triggering comprises generating a software interrupt.

5. The method of claim **1**, wherein the alert comprises an audible alarm or a visual display.

6. The method of claim **1**, wherein the threshold is predetermined based on theoretical or expected values of the echo energy.

7. The method of claim **1**, wherein the threshold comprises a selectively or dynamically adjustable threshold.

8. The method of claim **1**, further comprising adjusting the threshold in real time based on a communications parameter associated with the physical device.

9. The method of claim **8**, wherein the communications parameter comprises a bit error rate.

10. The method of claim **1**, wherein the alert includes a recommendation to clean contacts, replace a network cable, or reduce current levels.

11. A device for use in a Power over Ethernet application, the device comprising:

an echo canceller to remove echo energy from a signal received at a receiver; and

a tap monitor configured to:

monitor operation of said echo canceller;

compute a value of the echo energy over time; and

responsive to a determination that the computed value of the echo energy over time is above a threshold, which indicates a saturation condition, trigger an alert to indicate unbalanced current as a cause of the saturation condition.

12. The device of claim **11**, wherein said tap monitor is configured to monitor tap adaptations of said echo canceller to identify areas representative of the computed value of the echo energy over time being above the threshold.

13. The device of claim **11**, wherein the output from said tap monitor is employed to set one or more bits in a hardware register at the device.

14. The device of claim **11**, wherein the output from said tap monitor is employed to generate a software interrupt at the device.

15. The device of claim **11**, wherein the alert comprises an audible alarm or a visual display.

16. The device of claim **11**, wherein the threshold is predetermined based on theoretical or expected values of the echo energy.

17. The device of claim **11**, wherein the threshold comprises a selectively or dynamically adjustable threshold.

18. The device of claim **11**, wherein the threshold varies, in real time, in accordance with a communications parameter.

19. The device of claim **18**, wherein the communications parameter comprises a bit error rate.

20. The device of claim **11**, wherein the alert comprises a recommendation to clean contacts, replace a network cable, or reduce current levels.

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